



TIMARIS

PVD Production Platform
for Semiconductor &
Magnetic Storage

TIMARIS

Deposition of Ultra-thin Metallic and Insulating Films down to a Thickness of one Nanometer and below and Stacks of such Films with very Precise Material Thickness and High Uniformity Specifications

TIMARIS Cluster Tool

SINGULUS TECHNOLOGIES is a renowned manufacturer of advanced thin-film deposition equipment for MRAM, thin-film head, sensor and other semiconductor applications. It is the trusted partner in the respective industry and extends its leadership in the thin-film deposition technology for semiconductor applications.

SINGULUS has already established and qualified the second generation of the TIMARIS PVD Cluster Tool platform in the market and is offering a complete portfolio of process modules for different applications.

As of today, more than ten process modules are available to configure a TIMARIS system according to customer needs. These modules include the Multi-Target-Module (MTM), Oxidation-Process-Module (OPM),



TIMARIS

Advanced
Deposition System

Pre-Clean-Module (PCM), Combi-Process-Module (CPM), Four-Target-Module (FTM) and Static-Deposition-Module (SDM) as well as the Rotating-Substrate-Module (RSM). The RSM is the core module of the ROTARIS platform, our sputtering system for special R&D applications.

The TIMARIS PVD modules (FTM , iPVD, MTM, RSM and SDM) incorporate the full scope of sputtering techniques as: DC magnetron sputtering, pulsed DC magnetron sputtering and RF magnetron sputtering as well as combinations of these modes are selectable by recipe.

PVD Cluster Tool Platforms

ROTARIS

Applied
R&D

TIMARIS II Platform

R&D and Pilot
Production

TIMARIS III

Volume
Production



TIMARIS Applications

PVD Production Platform for Semiconductor & Magnetic Storage

Applications

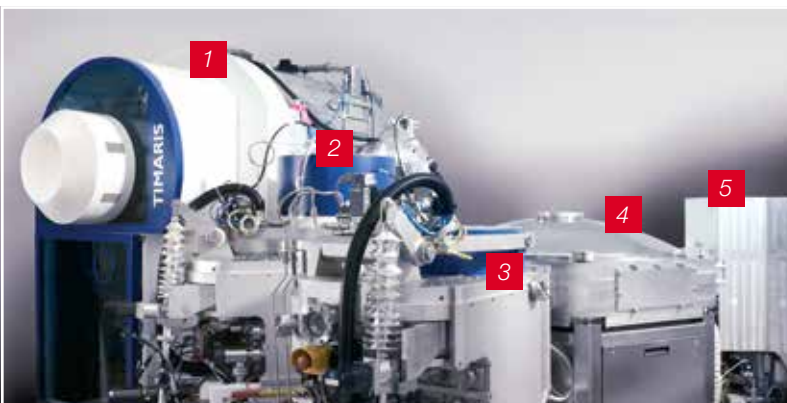
- TMR, pTMR – MRAM
- Magnetic sensor (GMR, AMR, TMR)
- Integrated inductors
- Integrated voltage regulator (Buck Converter)
- MEMS
- High moment materials
- TFH reader & writer
- Semiconductors

All TIMARIS applications require the deposition of ultra-thin metallic and insulating films and film stacks down to a thickness of one nanometer and below with very precise material thickness and high uniformity specifications.

The MTM and the FTM are the key components of the TIMARIS platform; the MTM incorporates the Linear Dynamic Deposition (LDD, US patent US 7,799,179 B2) technology in combination with ten sputter targets in one vacuum chamber.

The FTM module uses Linear Dynamic Deposition in combination with up to four cathodes. The LDD technology is especially designed for deposition of ultra-thin films, magnetic films, high-quality metallic, conductive and insulating films and is the key to deliver world class material uniformity across large wafer sizes, combined with an exceptional precise control of ultra-thin layer thickness down to 1 % of a nanometer.





1 Multi-Target-Module

*Top: Target drum with 10 rectangular cathodes; drum design ensures easy maintenance;
Bottom: Main part of the chamber containing LDD equipment*

2 Oxidation Module

*Low energy remote atomic plasma oxidation;
natural oxidation; low energy surface treatment*

3 Pre-Clean-Module

(Pre-Clean, surface treatment)

4 Transport Module

(UHV wafer handler)

5 Load Port

(according to customer specification)



TIMARIS Platform

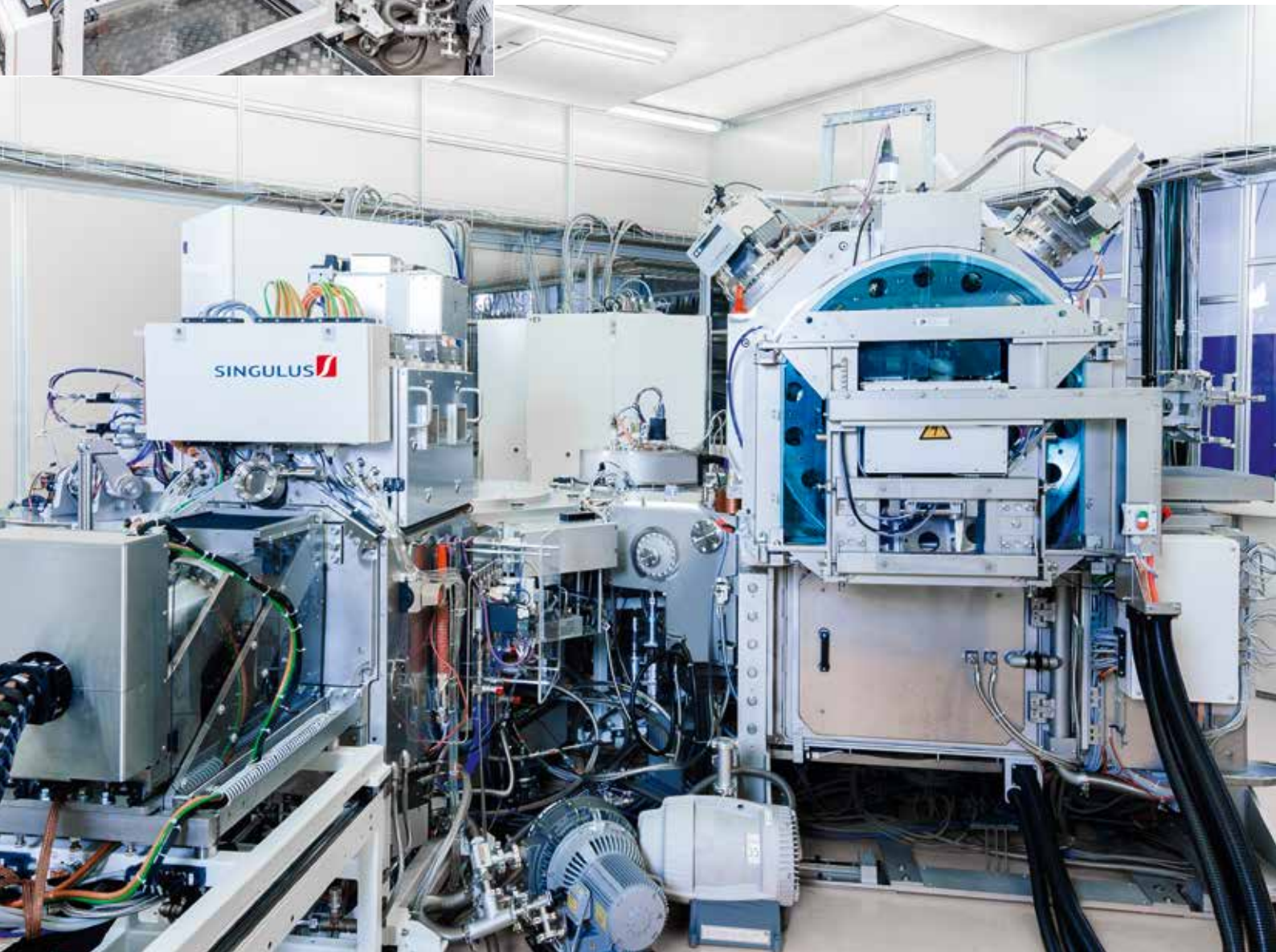
PVD Production Platform for Semiconductor & Magnetic Storage



TIMARIS II & TIMARIS III

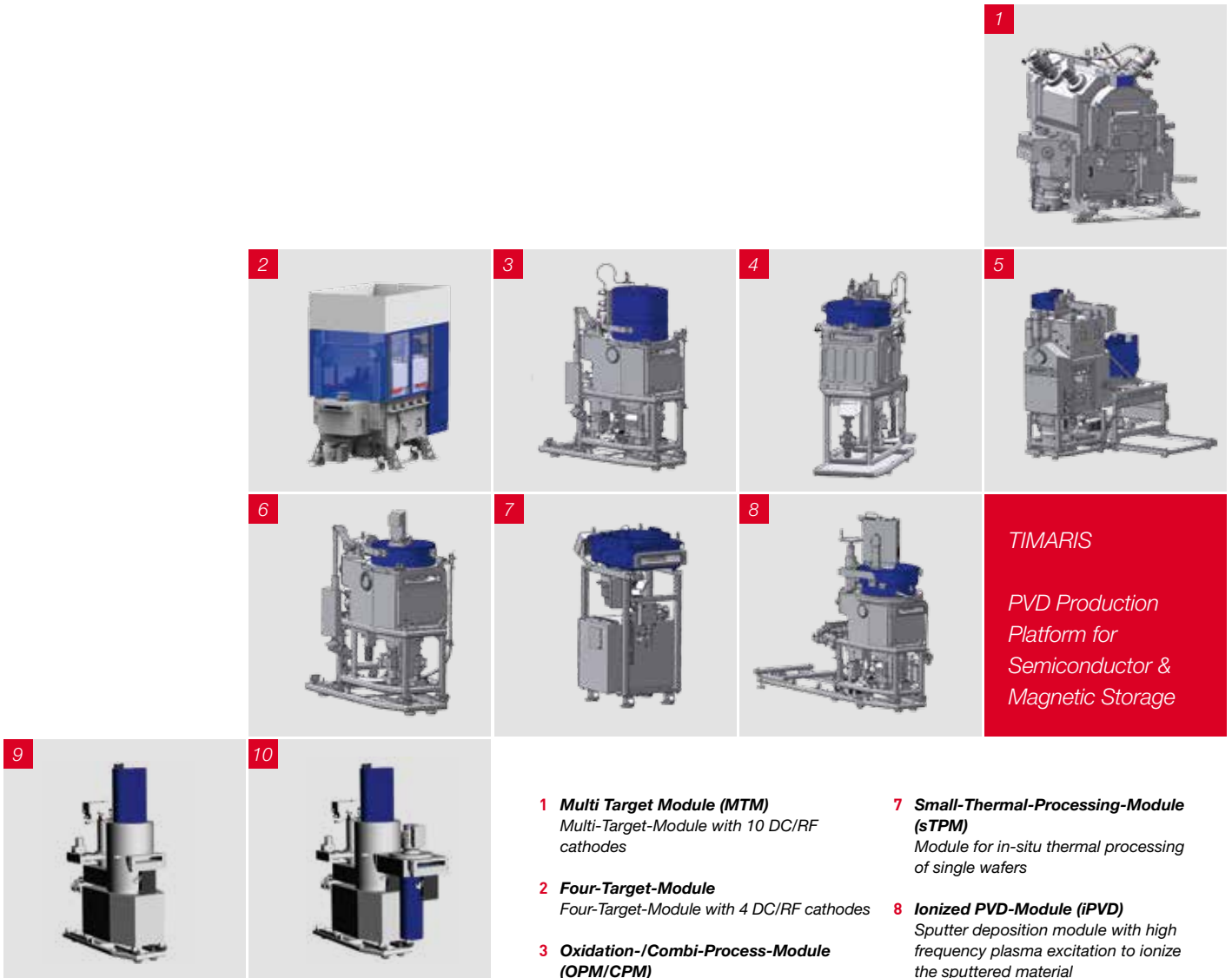
Ultra-high vacuum design	Base pressure < 5*10 ⁻⁹ Torr (deposition chamber)
High throughput (e.g. MRAM,STT-RAM)	20 Wafer/h and above*
High effective up-time	Maintenance friendly design
Reliability	Solid and well engineered design, no fast moving parts

* depending on layer stack



TIMARIS

Multi-Cathode Deposition Platform for Various Semiconductor and Magnetic Storage Applications



1 Multi Target Module (MTM)

Multi-Target-Module with 10 DC/RF cathodes

2 Four-Target-Module

Four-Target-Module with 4 DC/RF cathodes

3 Oxidation-/Combi-Process-Module (OPM/CPM)

Oxidation of ultra-thin metallic films into insulating films/oxidation and pre-clean in one module

4 Pre-Clean-Module (PCM)

Cleaning of wafer prior to deposition

5 Rotating-Substrate-Module (RSM)

Modular vacuum deposition for applied research in semiconductor industry and other areas

6 Static-Deposition-Module (SDM)

High rate sputter deposition of metallic and non-conducting materials

7 Small-Thermal-Processing-Module (sTPM)

Module for in-situ thermal processing of single wafers

8 Ionized PVD-Module (iPVD)

Sputter deposition module with high frequency plasma excitation to ionize the sputtered material

9 Rapid-Thermal-Process-Module (rTPM)

In-situ thermal processing of wafers with temperatures up to 600 °C with high wafer throughput

10 Rapid-Oxidation-Process Module (rOPM)

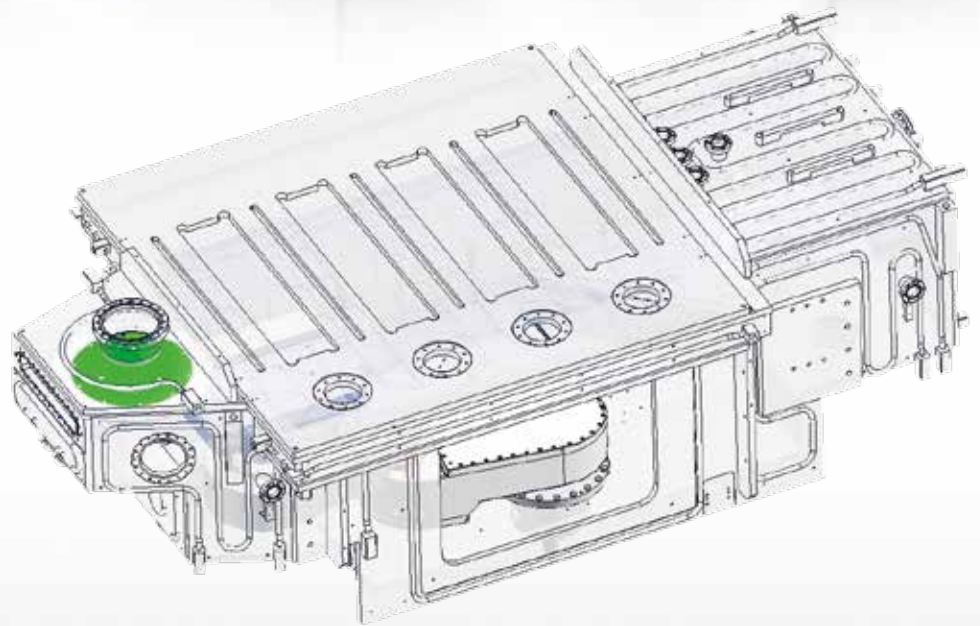
In-situ natural oxidation of wafers with high wafer throughput

Linear Dynamic Deposition (LDD)

Deposition Technique:

Linear PVD Magnetron and Linear Movement of Wafer

LDD



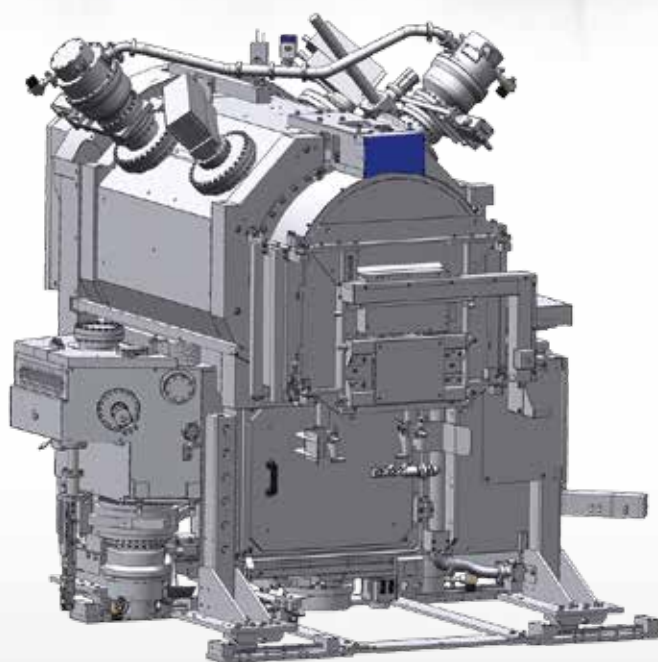
- Short target-substrate distance:
 - Best coating efficiency
 - Low cost of ownership
- Thickness adjusted by wafer speed:
 - Precise thickness control & repeatability
 - Ultra thin-film < 0.1 nm; smallest thickness step: < 0.01 nm
- Special LDD capabilities:
 - Deposition of thickness wedges
 - Preparation of concentration gradients
- Multi-directional coating:
 - Smooth films and interfaces
- Stationary Aligning Magnetic Field (AMF):
 - Magnetic pre-alignment of easy axis direction
- Leakage field of cathode parallel to wafer travel direction:
 - Ideal symmetry for magnetic film applications
 - Robust and reliable design



Multi-Target-Module (MTM)

Multi-Target-Module with 10 DC/RF Cathodes

MTM



Multiple film stack deposition, without the need to break ultra-high vacuum, is one of the key advantages of the MTM process module. Additional features such as wafer heating for hot substrate deposition (option) or a collinear Aligning Magnetic Field (AMF) are available. The AMF can be activated to align the magnetic easy axis during deposition of ferromagnetic films.

The Linear Dynamic Deposition (LDD) technology enables the capability to deposit wedge films with a different film thickness across the wafer and to deposit alloy films with adjustable concentration gradients across one wafer. Both features allow a very cost effective development of film stacks and accelerate the devices development.

The LDD technology is the key to delivering world class material uniformity across large wafers and exceptional precise control of ultra- thin layer thickness down to 1 % of a nanometer.

Details:

- DC/RF magnetron
- All sputter deposition modes selectable by recipe for all 10 cathodes
- LDD technology
- RF bias option
- Ultra-high vacuum technology, base pressure $< 8 \cdot 10^{-9}$ Torr
- Wafer heating and cooling (options)



Four-Target-Module (FTM)

Four-Target-Module with 4 DC/RF Cathodes

FTM

The Four-Target-Module (FTM) incorporates Linear Dynamic Deposition (LDD) technology in combination with up to four sputter targets in one vacuum chamber.

The FTM incorporates the same functionalities like the Multi-Target-Module (MTM) such as the substrate heating, the Aligning Magnetic Field (AMF) and the capability to deposit wedge films with a different film thickness across the wafer and to deposit alloy films with adjustable concentration gradients across one wafer. The only difference of the FTM is the number of targets. It is particularly designed for deposition of periodic multi-layers with high wafer throughput



Details:

- DC/RF magnetron
- All sputter deposition modes selectable by recipe for all 4 cathodes
- LDD technology
- RF bias option
- Ultra-high vacuum technology, base pressure $< 8 \cdot 10^{-9}$ Torr
- Wafer heating and cooling



Pre-Clean-Module (PCM)

Cleaning of Wafer prior to Deposition

PCM

The Pre-Clean-Module (PCM) is used to clean the wafer prior to deposition. This is a standard technique employing sputter etch technology by applying RF power to the wafer. Typically, the process removes residual water and other molecules and native oxides by adjusting the etching process parameters. Optionally, this module can also be equipped with an ECWR plasma source. This additional plasma source provides a more flexible etching process (higher etch rates, lower etching energies). The module geometry (large plasma source, rotational symmetric pump system) ensures a high uniformity of the etching.



Details:

- Wafer cleaning, removal of native oxides by sputter etch
- ECWR plasma source as option
- Variable distance between substrate and ion source
- Degas heater as option
- Ultra-high vacuum technology, base pressure $< 5 \cdot 10^{-8}$ Torr



Oxidation-/Combi-Process-Module (OPM/CPM)

Oxidation of Ultra-thin Metallic Films into Insulating Films/Oxidation and Pre-clean in one Module

OPM/CPM

The Oxidation-Process-Module (OPM) is required to oxidize ultra-thin metallic films into insulating films of very high quality. Such films are required in tunnel magneto resistance layer stacks as tunneling barriers. The oxidation can be performed by using a remote plasma provided by a ECWR plasma source. This source generates oxygen ions and radicals of very low adjustable energy. Alternatively, the oxidation can be performed by the so-called natural oxidation by exposing the metal film to pure oxygen of low pressure (10 Torr down to 0.1 m Torr). The module geometry (large plasma source, rotational symmetric pump system) ensures a high uniformity of the oxidation.

The Combi-Process-Module (CPM) comprises both technologies of oxidation and pre-clean in one module. This is a cost-efficient option, since only one module for two process steps is required. It is mainly envisaged for R&D purposes, where a high throughput is of less importance. The process performance is identical with the Oxidation-Module and the Pre-Clean-Module.



Details:

- Low energy remote plasma oxidation
- Natural oxidation
- Surface treatment by low energetic ions
- Wafer cleaning, removal of native oxides by sputter etch
- Variable distance between substrate and ion source
- Ultra-high vacuum technology, base pressure $< 5 \cdot 10^{-8}$ Torr



Rotating-Substrate-Module (RSM)

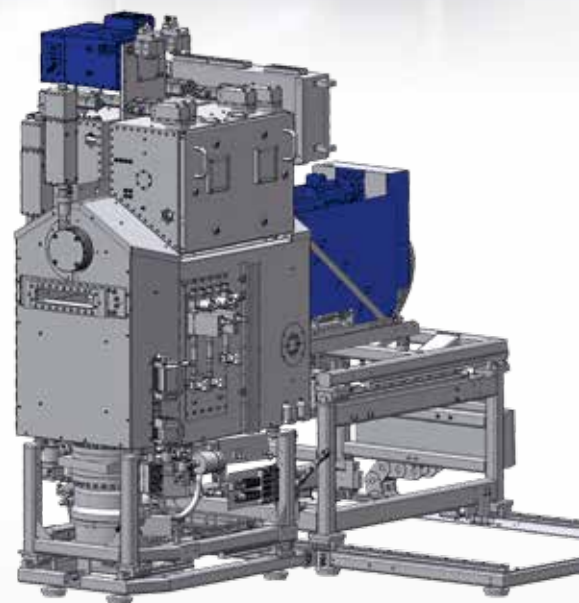
*Modular Vacuum Deposition for Applied Research
in Semiconductor Industry and other Areas*

RSM

The name-giving characteristic feature of the RSM is the sputter deposition onto a rotating substrate. Tilting of the substrate stage as well as the rotating speed are parameters to control the properties of the deposited films. The RSM can be equipped with up to 12 PVD cathodes with a target diameter of 100 mm. Co-sputtering with up to four cathodes utilizing DC/pulsed DC and RF mode are additional important technologies for any R&D work. The ultra-high vacuum base pressure down to $< 10^{-8}$ Torr makes the RSM a perfect tool for depositing extremely thin films and stacks of such films as typical for magneto-electronic applications. The RSM is the core module of SINGULUS' ROTARIS platform.

Applications:

- Material evaluation due to co-sputter
- Low initial costs on targets – COO
- Flexible process configuration
- Small footprint



Details:

- 300 mm and 200 mm wafer
- Up to 12 PVD cathodes, target Ø 100 mm
- Co-sputtering
- DC/RF sputtering
- Base pressure $< 10^{-8}$ Torr
- Ion beam source (option)
- In-situ aligning magnetic field (option)
- Wafer heating (option)

Static-Deposition-Module (SDM)

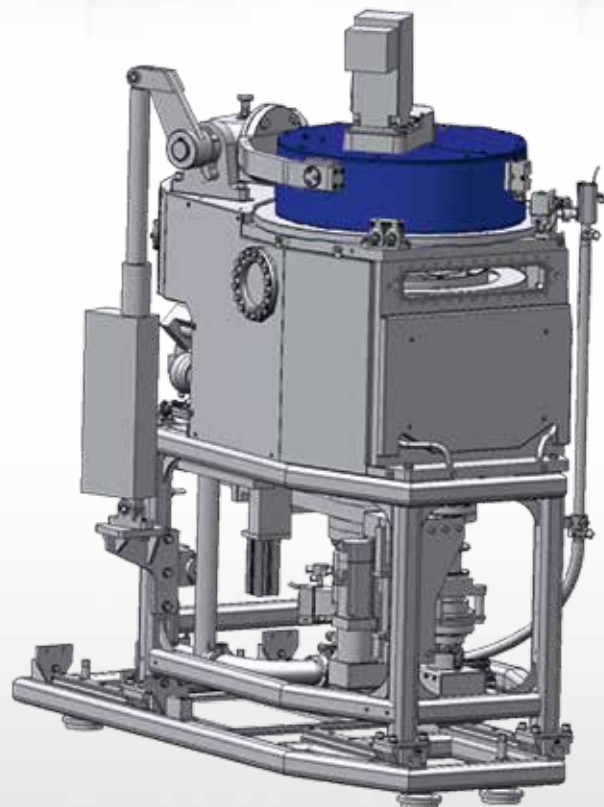
High Rate Sputter Deposition of Metallic and Non-conducting Materials

SDM

The Static-Deposition-Module (SDM) comprises a standard magnetron cathode with optimized target utilization for high rate sputter deposition of metallic and non-conducting materials for multiple applications. DC magnetron as well as RF magnetron sputter modes are selectable through a recipe menu. The module is envisaged to be used for deposition of films with high deposition rate that do not require the extremely high uniformity that can be achieved by the LDD technology.

Details:

- DC and RF sputter deposition selectable by recipe
- Variable distance between substrate and sputter target
- Ultra-high vacuum technology, base pressure $< 5 \cdot 10^{-8}$ Torr

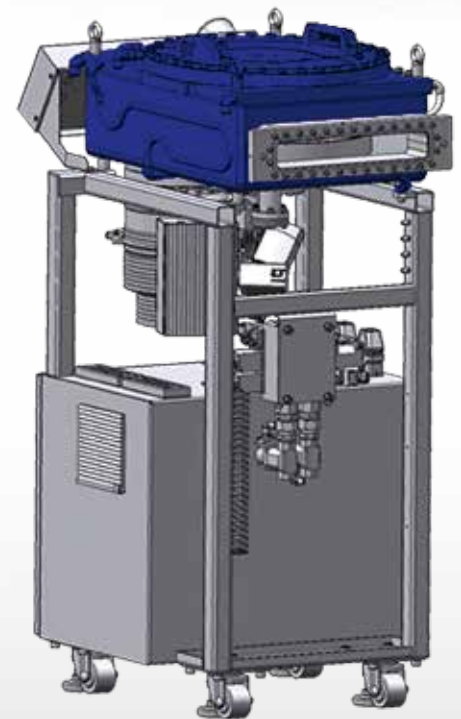


Small-Thermal-Processing-Module (sTPM)

R&D Version for Thermal Processing of Wafers

sTPM

Module for in-situ Thermal Processing of single Wafers. This module allows to bake a substrate (wafer) within the system without breaking the vacuum and subsequent further deposition.



Details:

- Thermal Processing by Annealing of wafers
- Ultra High Vacuum back pressure $< 1 \cdot 10^{-8}$ Torr
- Ultra High Vacuum back pressure during annealing $< 5 \cdot 10^{-8}$ Torr
- Temperature up to 600 °C
- High temperature uniformity
- High temperature stability

Ionized PVD-Module (iPVD)

Sputter Deposition Module with Ionized Sputtered Material

iPVD

Sputter deposition module with high frequency plasma excitation to ionize the sputtered material. Together with substrate bias as well as by applying a magnetic field perpendicular to the wafer plane deep trenches and holes can be filled with the sputtered material.

Details:

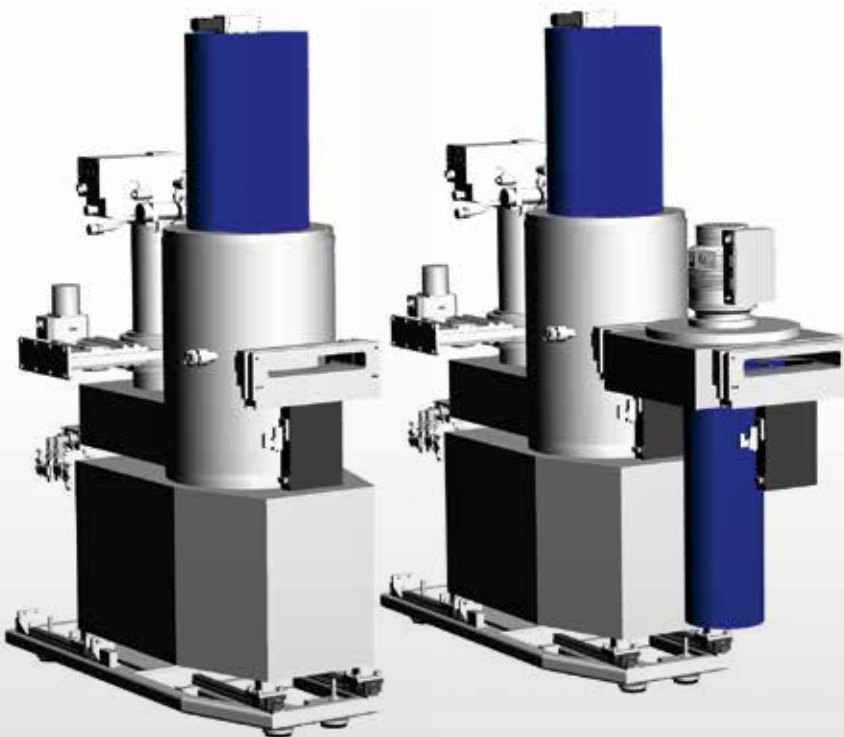
- 300 mm and 200 mm wafer operation
- One sputter deposition cathode
- DC/pulsed DC or RF sputtering
- ICP plasma excitation
- Toroidal coil to generate a perpendicular magnetic field
- RF substrate bias
- Base pressure $< 5 \cdot 10^{-8}$ Torr



Rapid-Thermal- and Oxidation-Process Module (rTPM/rOPM)

Modules to Provide In-situ Thermal Processing and Natural Oxidation Process with High Wafer Throughput

rTPM/rOPM



The rTPM provides in-situ thermal processing of wafers with temperatures up to 600 °C with high wafer throughput. By the rOPM a "natural" oxidation process is provided as well with a high wafer throughput. Both modules are basically utilizing the same "fifo" technique to allow a pseudo-simultaneous wafer processing.

Details:

- 300 mm and 200 mm wafer operation
- Base pressure < $5 \cdot 10^{-8}$ Torr
- High wafer throughput (recipe dependent)
- **rTPM**
 - Wafer temperature up to 600 °C
 - Long heating time (adjustable be recipe)
- **rOPM**
 - Natural oxidation: exposure of wafers to pure oxygen, pressure range $1 \cdot 10^{-4}$ to 10 Torr
 - Long oxidation time (adjustable be recipe)
 - Separation lock between rOPM and transport platform

TIMARIS II – 300 mm Wafer

The footprint shown consists of:

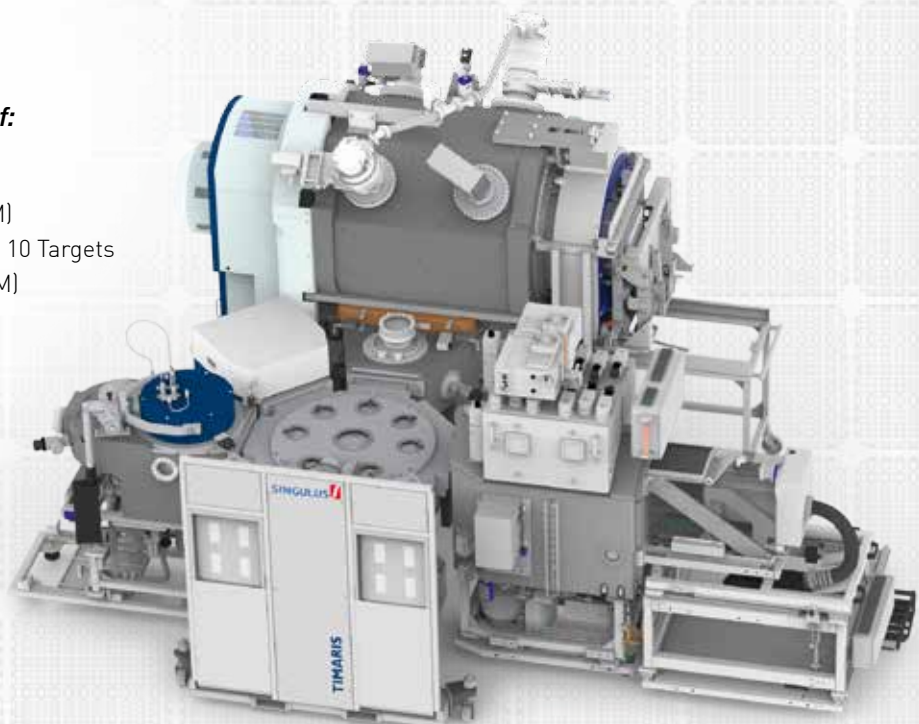
- 2 Multi-Target-Modules
- Combi-Process-Module (CPM)
- 1 Transport Module including EFEM and 2 FOUP Loadports
- Multiple wafer handling
- Throughput: up to 20 Wafer with standard MRAM layer stack
- Software integration: GEM/SECSII Interface



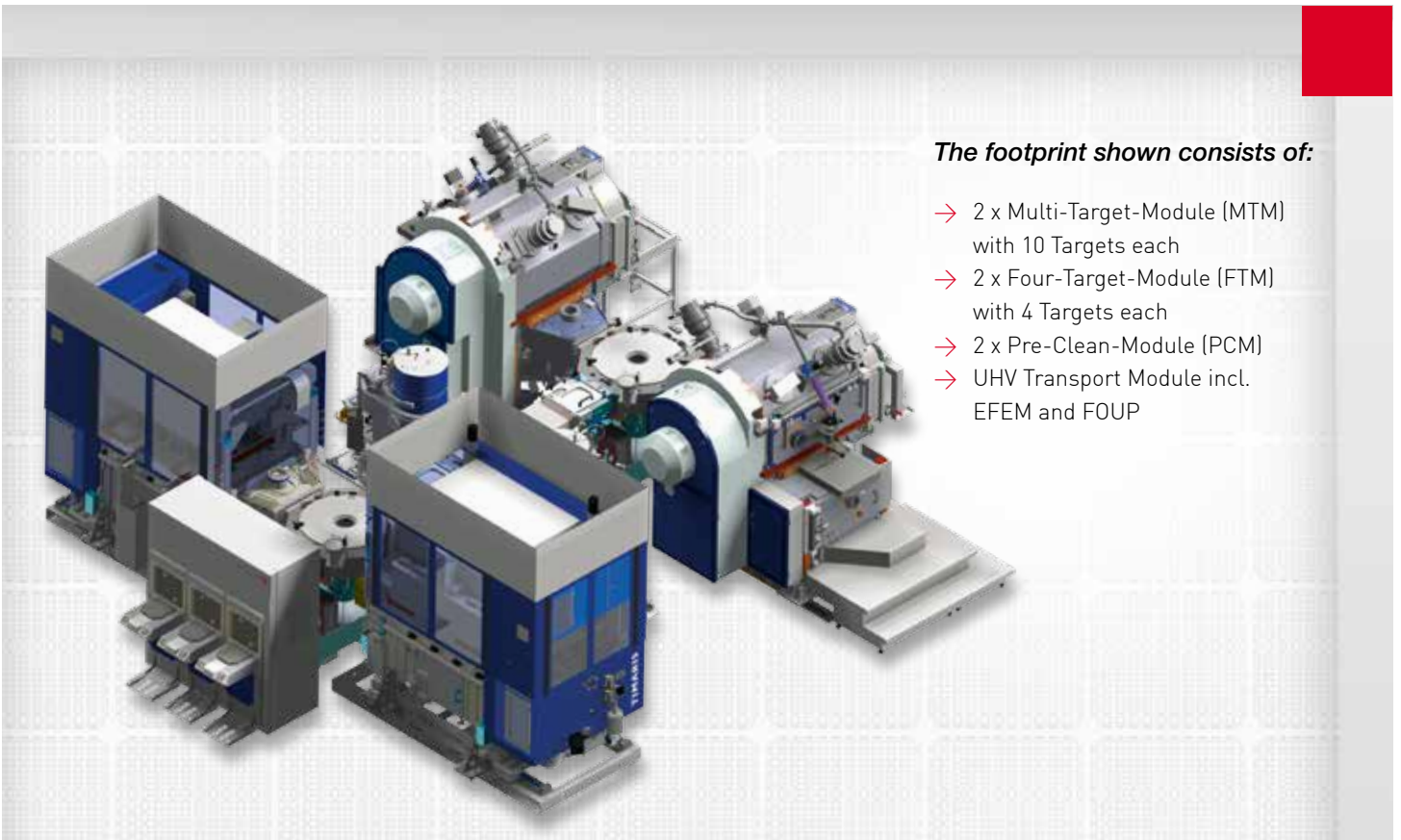
TIMARIS II – 200 mm Wafer

The footprint shown consists of:

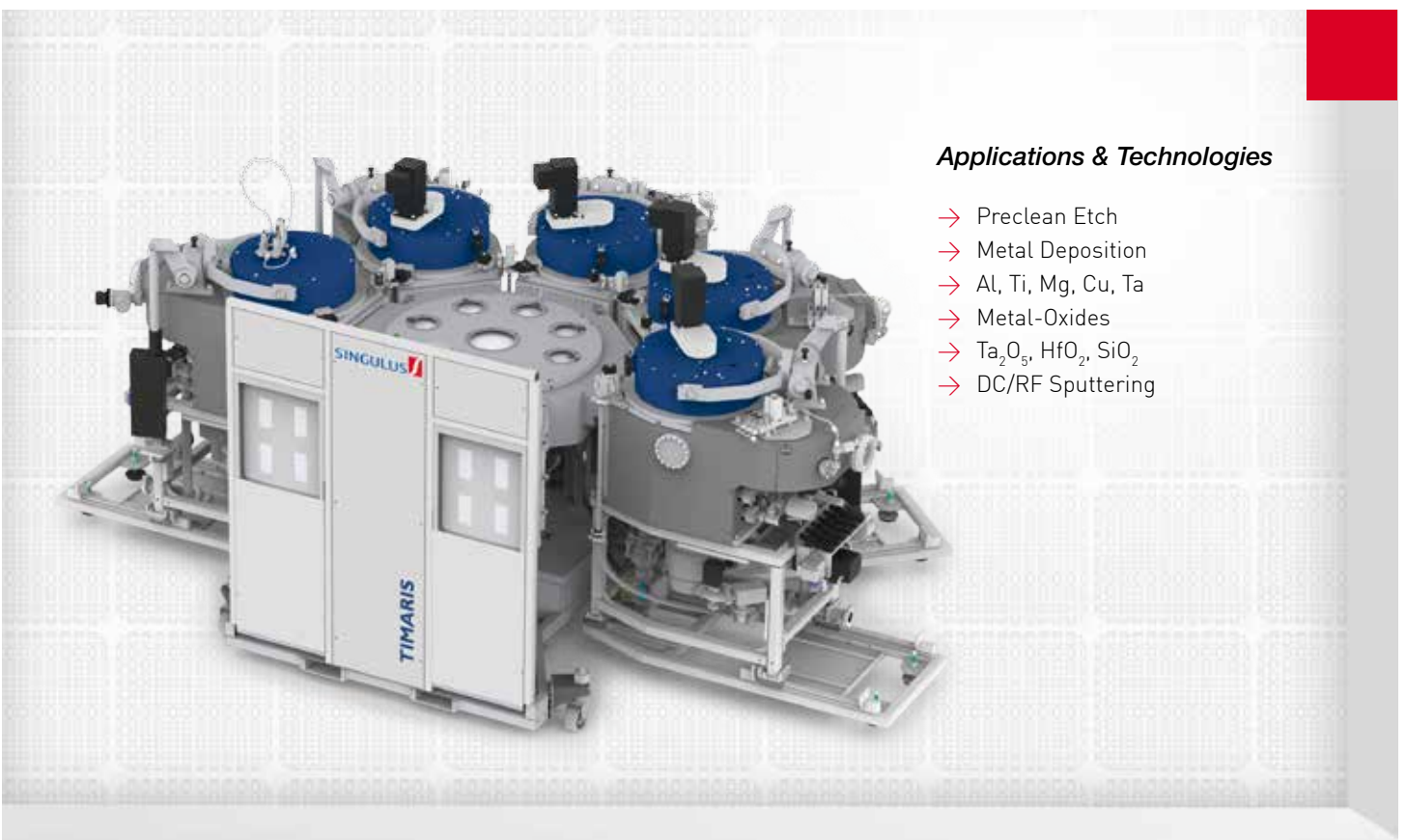
- Pre-Clean-Module (PCM)
- Thermal-Process-Module (sTPM)
- Multi-Target-Module (MTM) with 10 Targets
- Rotating-Substrate-Module (RSM)
- Vacuum-Transport-Module with cassette loading



TIMARIS III – 300 mm Wafer High Volume Production



TIMARIS – 200 mm Wafer





Headquarters

SINGULUS TECHNOLOGIES AG

Hanauer Landstrasse 103
D - 63796 Kahl, Germany
Tel. +49 6188 440-0
Fax +49 6188 440-130
sales@singulus.de
www.singulus.de

Production Site for Wet Processing Systems

SINGULUS TECHNOLOGIES AG

Niederlassung Fürstfeldbruck
Fraunhoferstr. 9
82256 Fürstfeldbruck
Tel. +49 8141 3600-0
Fax +49 8141 3600-100
sales@singulus.de

China

SINGULUS TECHNOLOGIES SHANGHAI

Tel. +86 13918298537
greens.pan@singulus.com.cn

France

SINGULUS TECHNOLOGIES FRANCE S.A.R.L.

Tel. +33 3 893111-29
singulus@club-internet.fr

Latin America

SINGULUS TECHNOLOGIES LATIN AMERICA LTDA.

Tel. +55 1121 6524-10
rodolfo.mignone@singulus.com.br

Singapore

SINGULUS TECHNOLOGIES ASIA PACIFIC PTE LTD.

Tel. +65 674 119-12
sales@singulus.com.sg

Taiwan

SINGULUS TECHNOLOGIES TAIWAN LTD.

Tel. +886 2 2748-3366
sales@singulus.com.tw

United States and Canada

SINGULUS TECHNOLOGIES INC.

Tel. +1 860 68380-00
sales@singulus.com



THIN FILM
DEPOSITION

SURFACE
ENGINEERING

THERMAL
PROCESSING

WET
CHEMICAL

SINGULUS TECHNOLOGIES – Innovations for New Technologies

SINGULUS TECHNOLOGIES builds machines for economical and resource-efficient production processes.

SINGULUS TECHNOLOGIES' strategy is based on the use and expansion of its existing core competencies. The application areas include coating technology, surface processing, wet-chemical applications as well as the related chemical and physical processing steps. The company's target is to reach a technologically leading position in the Solar division.

For all machines, processes and applications SINGULUS TECHNOLOGIES draws upon its know-how in the areas of automation and process technology.